A PRECISION CHRONOGRAPH

CONSTRUCTED BY THE REV. FATHER LEJAY OF THE ZI-KA-WEI OBSERVATORY.

The Rev. Father LEJAY, in his very exhaustive article published in the *Journal des Observateurs*, August 15, 1929, points out that when attempts are made to measure the duration of a phenomenon to a greater accuracy than one-hundredth of a second, one is brought face to face with a certain number of obstacles, which it is difficult to overcome with the chronographs now in use.

Chronographs which record directly on strips of smoked paper, so handy for use when the hundredth part of a second only is required, are already under suspicion for measuring thousandths of seconds.

To be sure, by making the moving parts of oscillographs lighter and, particularly, by diminishing the strength of the counteracting spring, sharp reaction of the stylus is obtained, but the irregularities in unwinding of the paper between two consecutive seconds of the standard pendulum entail considerable risk of error in the readings.

It therefore becomes necessary to place intermediate marks between these seconds and for this purpose tuning forks are generally used, The reading of the paper records is consequently very difficult for the oscillations of the tuning fork must be counted one by one over considerable lengths to ascertain its exact period, read off the fractions of residual vibrations, and calculate the elapsed time which they represent.

The use of *Abraham's Multivibrator*, which automatically divides the second into smaller fractions and is corrected at each second, without doubt considerably economises time, but it is perhaps a little less accurate than the tuning fork. In any case with this type of chronograph, it would be quite impossible to reach greater accuracy than a thousandth.

Photographic chronographs of to-day usually record to a ten-thousandth of a second, but they are really intended more for the analysis of factory phenomena rather than for measuring time, and it is in laboratories that they are mostly used.

As a matter of fact the majority use strips of photographic paper which unwind at great speed, for to read to a ten-thousandth of a second it is necessary to unwind at least a metre per second. This unwinding is generally irregular and, in any case, the photographic paper is distorted during development, so that it is absolutely necessary to have check marks at very close intervals throughout the length of the paper. Here again the tuning fork has to be introduced and the difficulties already mentioned occur again in their entirety, and there are, also, the difficulties of manipulation and cost.

Besides, these instruments are rarely used for the measurement of elapsed time except in special tests such as the measurement of the velocities of projectiles, study of the propagation of wireless waves etc., in which the time elapsed is very small.

To investigate the regularity of constant pressure chronometres and of the small clock which is used for sending the time signals of the International Time Bureau, Father LEJAY constructed a model photographic chronograph which records a ten-thousandth of a second by direct reading, the graduation is automatic and its manipulation is as simple as possible. This type of chronograph can be used for a great deal of other research work also. Its principle is as follows:-

Principle of the Chronograph. — The record is made on a photographic cylinder upon which the pencil of light draws a helix the pitch of which is adjustable. A tuning fork, the period of which approximates closely to a hundredth of a second, interrupts the light-ray at each oscillation for a very short period in such a way that the regular reference marks, to which all readings are referred, are on the curve itself.

Further, the velocity of rotation of the cylinder, which is kept uniform by a governor, is such that the cylinder makes about two revolutions per second, *i. e.* during one hundred vibrations of the tuning fork. The reference marks are thus divided into fifties by each revolution and into hundreds by every alternate revolution of the cylinder.

In addition the distance between two consecutive reference marks is uniform to within less than one tenth of a millimetre, and thus an estimate of the fractions of oscillations of the tuning fork, in hundredths, can be ascertained by means of a definitely graduated scale.

To obtain this result it is not essential that the speed of rotation of the cylinder should be maintained very accurately nor that its movement should synchronise with the tuning fork; to arrange this would have been a complicated business, anyway. All that is required is a governor to keep the velocity in the neighbourhood of synchronism and this can easily be done, as will be seen, by the stroboscopic adjustment of an ordinary centrifugal governor.

Thus the chronograph is composed of very simple parts which are in daily use in laboratories, the adjustment of which is well known and which only require to be assembled to make one instrument.

The oscillograph is of the BLONDEL type: a small mirror, one millimetre square, stuck with lac between two parallel strands of a silver or bronze wire which is very thin but fairly taut, forms the movable equipment. The inertia of this system is low and its proper period nearly one ten-thousandth of a second. The whole is enclosed in an oil bath which ensures damping of oscillations.

A prism is interposed between the oscillograph and the cylindrical lens and is made to rotate about a vertical axis by means of an auxiliary spring-driven clockwork, fitted with a fan-governor with adjustable wings: the pencil of light is thus refracted horizontally on to the recording cylinder, whereon a helix is photographically reproduced without any movement parallel to its axis being necessary.

The end of the recording cylinder is fitted with a toothed wheel which is firmly secured to its axle, whereby the speed of rotation can be regulated in the following way:-

A tuning fork, electrically maintained without contact, is provided with a light frame which penetrates into the lantern in front of the vertical slit through which the luminous ray passes — a wire stretched across the frame closes the slit at each oscillation for some ten-thousandths of a second; as the tuning fork has a period of about one fiftieth of a second, interruptions occur on the record which graduate it very closely by one hundredths of a second.

By setting the prism in a suitable position the pencil of light may be made to fall on the toothed wheel attached to the axle of the recording cylinder. By looking through the teeth of this wheel the image of the wire attached to the tuning fork can be seen stroboscopically.

To steady the image it is only necessary to adjust the governor of the cylinder drive.